

(19) JAPANESE PATENT OFFICE

(12) UNEXAMINED PATENT PUBLICATION BULLETIN (A)

(11) Publication Number: 06-093381

(43) Date of publication of application: 05.04.1994

(51) Int. Cl. C22C 38/00
C22C 38/54
C22C 38/58

Request for examination: not yet requested Number of claims: 2 (9 pages total)

(21) Application Number: 03-326983

(22) Date of filing: 15.11.1991

(71) Applicant: 000004581
Nisshin Steel Co. Ltd.
3-4-1, Marunouchi, Ward of Chiyoda, Metropolis of Tokyo

(72) Inventors: KATO Hirohisa
Section Stainless and High Alloy Steel
Nisshin Steel Co. Ltd. Research Institute
4976, Nomura-minami-machi, Shin Nan'yo City
Prefecture of Yamaguchi

(72) Inventor KAWAI Yutaka
Section Stainless and High Alloy Steel
Nisshin Steel Co. Ltd. Research Institute
4976, Nomura-minami-machi, Shin Nan'yo City
Prefecture of Yamaguchi

(74) Patent Attorney WADA Kenji

Continued on the last page

(54) [Title of the Invention] High Expansion Alloy for Bimetals with High Workability

(57) [Abstract]

[Object]

An object of this invention is to provide a high expansion alloy for bimetals exhibiting excellent workability at high temperatures.

[Composition and Structure]

A high expansion alloy containing in weight percent: 0.5% carbon or less, 4% silicon or less, 8% manganese or less, 0.008% sulphur or less, 0.040% phosphorus or less, 8 to 30% nickel, 0.5 to 14% chromium, 0.2% nitrogen or less, 2% cobalt or less, and 4% aluminium or less: and one, two or all of the following elements, i.e. 0.001 to 0.030% boron, 0.05 to 2% titanium, and 0.001 to 1% zirconium: and, if necessary, 4% copper or less and/or 4% molybdenum or less: and balance iron and unavoidable impurities. The alloy exhibits a single-phase austenite structure at room temperature and satisfies the following formulae:

$$T = 0.067 \times (\% \text{ Ni}) + 0.244 \times (\% \text{ Cr}) \leq 3.9$$

$$E = 2.80 \times (\% \text{ Ni}) + 2.32 \times (\% \text{ Cr}) \geq 55.0$$

The alloy also has a coefficient of thermal expansion equal to or greater than $18 \times 10^{-6}/^{\circ}\text{C}$ within the temperature range from 30 to 100°C , and an electrical resistivity equal to or greater than $70 \mu \Omega \text{ cm}$.

[Claims]

1. A high expansion alloy containing in weight percent:

C: 0.5% or less
Si: 4% or less
Mn: 8% or less
S: 0.08% or less
P: 0.040% or less
Ni: 8-30%
Cr: 0.5-14%
N: 0.2% or less
Co: 2% or less
Al: 4% or less:

one, two or all of the following elements,

B: 0.001-0.030%
Ti: 0.05-2%
Zr: 0.001-1%:

balance iron and unavoidable impurities:

exhibiting a single-phase austenite structure at room temperature:

satisfying the following formulae:

$$T = 0.067 \times (\% \text{ Ni}) + 0.244 \times (\% \text{ Cr}) \leq 3.9$$

$$E = 2.80 \times (\% \text{ Ni}) + 2.32 \times (\% \text{ Cr}) \geq 55.0:$$

and having a coefficient of thermal expansion equal to or greater than $18 \times 10^{-6}/^{\circ}\text{C}$ within the temperature range from 30 to 100°C and an electrical resistivity equal to or greater than $70 \mu \Omega \text{ cm}$.

2. A high expansion alloy containing in weight percent:

C: 0.5% or less
Si: 4% or less
Mn: 8% or less
S: 0.08% or less
P: 0.040% or less
Ni: 8-30%
Cr: 0.5-14%
N: 0.2% or less
Co: 2% or less
Al: 4% or less:

one, two, or all of the followings elements,

B: 0.001-0.030%
Ti: 0.05-2%
Zr: 0.001-1%:

and, if necessary, either or both of the following elements,

Cu: 4% or less

Mo: 4% or less:

balance iron and unavoidable impurities:

exhibiting a single-phase austenite structure at room temperature,

satisfying the formulae:

$$T = 0.067 \times (\% \text{ Ni}) + 0.244 \times (\% \text{ Cr}) \leq 3.9$$

$$E = 2.80 \times (\% \text{ Ni}) + 2.32 \times (\% \text{ Cr}) \geq 55.0,$$

and having a coefficient of thermal expansion equal to or greater than $18 \times 10^{-6}/^{\circ}\text{C}^{\circ}$ within the temperature range from 30 to 100°C , and an electrical resistivity equal to or greater than $70 \mu \Omega \text{ cm}$.

[Detailed Description]

[0001]

[Technological Field]

The invention relates to a high expansion alloy used for bimetallic applications exhibiting remarkable workability at high temperatures.

[0002]

[Background]

Bimetallic strips formed by a low expansion metal, such as Invar alloys or common steel, mechanically or metallurgically bonded to a high-expansion alloy, such as stainless steel, are largely used in various electric applications as sensing elements or temperature control devices. As a high-expansion component, iron-nickel-chromium alloys, general-purpose material standardized under JIS C2530, are widely used in various applications.

[0003]

These alloys, however, suffer from the disadvantage that none of the JIS C2530 alloys indicates clearly its chemical composition. For this reason, iron-nickel-chromium alloys, such as a 22% nickel-3% chromium-balance iron alloy, obtained by adding chromium to 20-25% nickel-balance iron alloys with a high expansion property, are largely used as the high expansion component in thermostat bimetal applications. The most important characteristics for bimetallic elements are their coefficient of thermal expansion (α) at the temperature range from 30 to 100°C and electrical resistivity (ρ). The coefficient of thermal expansion (α) should be equal to or greater than 18×10^{-6} per $^{\circ}\text{C}$, and electrical resistivity equal to or greater than $70 \mu \Omega \text{ cm}$.

[0004]

Unfortunately, iron-nickel-chromium alloys are not readily workable at high temperatures and tend to generate edge cracking. Cracking of 1-20 mm long which appears on both ends of hot-rolling coils along the width direction, amplifies, if neglected, during ~~cold-rolling process~~. Supplementary processing, i.e. elimination of damaged parts, results in a lowering of production yield and therefore productivity.

[0005]

[Problems to be solved]

This invention provides a high-expansion alloy readily workable at high temperatures, which has a high thermal expansivity and a high electrical resistivity equivalent to those of high-expansion alloys such as an iron-20% nickel-3% chromium alloy or an iron-25% nickel-8.5% chromium alloy.

[0006]

[Means for solving the problems]

Through investigations made on thermal expansivities, electrical resistivities and workability at high temperatures of iron-nickel-chromium alloys, the inventors have discovered that the workability at high temperatures of these alloys can be remarkably increased by adding a proper amount of boron, titanium, or zirconium, while controlling the contents of sulphur and phosphorus. In particular, the inventors have discovered that impurities such as sulphur and phosphorus included in iron-nickel-chromium alloys with single-phase austenite structure tend to segregate to grain boundaries, cause embrittlement, and lower workability at high temperatures. Adding to the alloys an adequate amount of boron, titanium, and/or zirconium, while reducing the sulphur and phosphorus contents, can reinforce grain boundaries and, consequently, ameliorate workability at high temperatures.

Moreover, controlling the nickel and chromium contents allows the alloy to have a single-phase austenite structure at room temperature. The alloy proposed by this invention also exhibits an advantageous combination of high expansivity and high electrical resistivity.

[0007]

[Composition and Structure of the invention]

This invention proposes an alloy containing in weight percent:

C: 0.5% or less
Si: 4% or less
Mn: 8% or less
S: 0.08% or less
P: 0.040% or less
Ni: 8-30%
Cr: 0.5-14%
N: 0.2% or less
Co: 2% or less
Al: 4% or less:

one, two or all of the following elements,

B: 0.001-0.030%
Ti: 0.05-2%
Zr: 0.001-1%:

balance iron and unavoidable impurities:

exhibiting a single-phase austenite structure at room temperature:

satisfying the following formulae:

$$T = 0.067 \times (\% \text{ Ni}) + 0.244 \times (\% \text{ Cr}) \leq 3.9$$

$$E = 2.80 \times (\% \text{ Ni}) + 2.32 \times (\% \text{ Cr}) \geq 55.0:$$

and having a coefficient of thermal expansion equal to or greater than $18 \times 10^{-6}/\text{C}^\circ$ within the temperature range from 30 to 100°C and an electrical resistivity equal to or greater than $70 \mu \Omega \text{ cm}$.

This invention proposes another high expansion alloy containing in weight percent:

C: 0.5% or less
Si: 4% or less
Mn: 8% or less
S: 0.08% or less
P: 0.040% or less.
Ni: 8-30%
Cr: 0.5-14%
N: 0.2% or less
Co: 2% or less
Al: 4% or less:

one, two, or all of the followings elements,

B: 0.001-0.030%
Ti: 0.05-2%
Zr: 0.001-1%:

and, if necessary, either or both of the following elements,

Cu: 4% or less
Mo: 4% or less:

balance iron and unavoidable impurities:

exhibiting a single-phase austenite structure at room temperature,

satisfying the formulae:

$$T = 0.067 \times (\% \text{ Ni}) + 0.244 \times (\% \text{ Cr}) \leq 3.9$$

$$E = 2.80 \times (\% \text{ Ni}) + 2.32 \times (\% \text{ Cr}) \geq 55.0,$$

and having a coefficient of thermal expansion equal to or greater than $18 \times 10^{-6}/\text{C}^\circ$ within the temperature range from 30 to 100°C , and an electrical resistivity equal to or greater than $70 \mu \Omega \text{ cm}$.

[0008]

Obtained by multiple regression analysis, the functions T and E in this invention do not stand on any theoretical base.

[0009]

The grounds for determining the alloy composition will be detailed as follows.

C: carbon is an essential element for generating austenitic state. Carbon allows obtaining a single-phase austenite structure at room temperature. The maximum carbon content, however, should be set to 0.5%, because excessive carbon could cause a deterioration of corrosion resistance.

Si: silicon is a useful element to increase electrical resistivity. The maximum silicon content, however, should be 4%, because excessive silicon could cause a lowering of workability at high temperatures.

[0010]

Mn: manganese is a constituent element of austenite. It is necessary for obtaining a single-phase austenite structure at room temperature, but the content of 8% is largely sufficient.

S: sulphur lowers workability at high temperatures. For this reason, the sulphur content should be limited to 0.008% maximum to realize a high workability proposed by this invention.

P: phosphorus lowers workability at high temperatures. For this reason, the phosphorus content should be limited to 0.040% maximum, to obtain a high workability proposed by this invention.

[0011]

Ni: nickel is a constituent element of austenite. At least 8% nickel content is necessary to obtain not only a single phase austenite structure at room temperature but also a high coefficient of thermal expansion. However, the nickel content should be limited to 30% maximum, because excessive nickel, on the contrary, could lower the coefficient of thermal expansion.

Cr: the minimum chromium content should be 0.5% to obtain a single-phase austenite structure at room temperature. However, the content should be limited to 14% maximum, because excessive chromium could transform the phase structure and lower the coefficient of thermal expansion.

[0012]

N: a strong generating element for austenite as is carbon, nitrogen is necessary for obtaining a single-phase austenite structure at room temperature. However, the content should be limited to 0.2% maximum, because excessive nitrogen could lower workability at high temperatures.

Co: cobalt is a constituent element of austenite and useful in obtaining a single-phase austenite structure at room temperature. However, the content should be limited to 2% maximum, because cobalt does not exert a significant influence on thermal expansion properties in spite of its rather high cost.

Al: aluminium is necessary to increase the electrical resistivity. However, the content should be limited to 4% maximum, because excessive aluminium could deteriorate workability.

[0013]

B: boron is a useful element which can increase workability at high temperatures without exerting a strong influence on both α and p . Adding 0.001% boron or more can increase significantly workability at high temperatures. However, the content should be limited to 0.030% maximum, because excessive boron tends to produce boride, which could lower workability at high temperatures.

Ti: titanium is a useful element which can increase not only p almost without lowering α , but also workability at high temperatures. Adding 0.05% titanium or more can significantly improve workability at high temperatures. However, the content should be limited to 2% maximum, because excessive titanium could deteriorate surface quality of steel band.

Zr: zirconium is a useful element which can increase not only p almost without lowering α , but also workability at high temperatures. Adding 0.001% zirconium or more can improve significantly workability at high temperatures. However, the content should be limited to 1% maximum, because excessive zirconium, on the contrary, could deteriorate workability at high temperatures.

Auxiliary material used for incorporating nickel may be contaminated with cobalt; however, if not exceeding 2%, the presence of an extra amount of cobalt could be tolerated, because this does not exert any influence on the properties claimed by this invention.

[0014]

Cu: the presence of copper is, as is nickel, necessary for obtaining a single-phase austenite structure at room temperature. However, the content should be limited to 4% maximum, because excessive copper could lower the coefficient of thermal expansion and electrical resistivity.

Mo: the presence of molybdenum is necessary for obtaining a single-phase austenite structure at room temperature. However, the content should be limited to 4% maximum, because molybdenum exceeding 4% could lower the coefficient of thermal expansion.

[0015]

[Embodiment of the Invention]

A preferred embodiment of the invention will now be described with reference to the accompanying drawings.

FIGURE 1 shows reductions in area (ϕ) measured by a tensile test carried at 1,000 °C on test alloys which are divided into two groups, the one with boron and the other without boron. The alloys without boron exhibit a reduction in area equal to or smaller than 80%, while the boron added alloys exhibit a much more favourable reduction in area, which results in a higher workability at high temperatures.

FIGURES 2, 3, and 4 show respectively the effect induced by the addition of boron, titanium, and zirconium to a 20 nickel-5 chromium-iron alloy on reduction in area (ϕ) measured at 1000°C, on coefficient of thermal expansion measures between 30 and 100°C, and on electrical resistivity measured at room temperature. These figures show that adding a proper amount of these elements can not only improve remarkably reduction in area and consequently workability at high temperature, but also contribute largely to ameliorate the value of p .

[0016]

FIGURES 5 and 6 show the influence of nitrogen and chromium exerted on α and ρ . The data of single phase austenite alloys (A) and those of an austenite-martensite phase alloy (A+M) shown in these figures reveal that an A+M phase alloy exhibits much lower α values and that their values of ρ vary widely. As for the values of α and ρ of the single-phase austenite (A) alloys, they can be arranged according to the concentration of Ni or Cr. The values of α and ρ can be determined univocally by the following formulae:

$$T = 0.067 \times (\% \text{ Ni}) + 0.244 \times (\% \text{ Cr})$$

$$E = 2.80 \times (\% \text{ Ni}) + 2.32 \times (\% \text{ Cr}).$$

For satisfying $\alpha \geq 18 \times 10^{-6}/^{\circ}\text{C}$, T should be ≤ 3.9 , and simultaneously, for satisfying $\rho \geq 70 \mu\Omega \text{ cm}$, E should be ≥ 55.0 .

[0017]

An application example will be given hereafter.

TABLE 1 lists the chemical composition, the coefficient of thermal expansion in the temperature range from 30 to 100°C, the electrical resistivity at room temperature, phase structure at room temperature and the length of edge cracking after a hot-working process of alloys proposed by this invention, traditional alloys, and alloys for comparison. In the Table 1, A stands for single austenite phase and A+M for austenite/martensite phase observed at room temperature. A1 and A2 are respectively the traditional 22Ni-3Cr-iron alloy and the traditional 25Ni-8.5Cr-iron alloy. B1 to B27 are the alloys proposed by this invention, while C1 to C17 are the alloys for comparison.

An ingot of 12 kg of each alloy was prepared in a vacuum induction melting furnace for evaluating workability at high temperatures. Test pieces cut from these ingots were heated to 1180°C and then hot-rolled to 3.0 mm thickness. Workability was evaluated according to cracking state observed.

[0018]

Furthermore, test pieces measuring the coefficient of thermal expansion (1.5 mm thick, 5 mm wide, and 50 mm long) and those measuring electrical resistivity (1.5 mm thick, 3 mm wide, 200 mm long) were prepared through the process including the following steps: forging / hot-rolling / annealing / cold-rolling / annealing. Coefficients of thermal expansion were measured within the temperature range from 30 to 100°C, and electrical resistivities at room temperature (approx. 25°C). The measuring results are shown in Table 1.

[0019]

[TABLE 1]

Table 1

No.	Chemical composition (mass %)													T	E	C.T.E. ($\times 10^{-6}/^{\circ}\text{C}$ 30~100 $^{\circ}\text{C}$)	Electrical resistivity at room temperature (μGcm)	Structure at room temperature	Edge cracking length	Remark		
	C	Si	Al	P	S	Bi	Ce	N	Ar	Co	Fe	Ti	Zr								Cu	Nb
1-1	0.11	0.21	0.36	0.005	0.005	22.1	3.1	0.01	0.005	0.01	0.001	0.001	0.001	0.01	0.01	2.24	59.07	19.4	79	A	10	Alloys proposed by this invention
2	0.01	0.78	0.75	0.010	0.002	25.3	8.5	0.01	0.005	0.01	0.001	0.001	0.001	0.01	0.01	1.77	90.86	18.1	83	A	20	
3-1	0.12	0.25	0.39	0.010	0.004	9.85	12.07	0.01	0.005	0.16	0.005	0.001	0.001	0.01	0.01	1.61	55.58	16.1	70	A	0	
2	0.11	0.18	0.36	0.022	0.003	12.56	8.18	0.01	0.005	0.09	0.005	0.005	0.002	0.01	0.01	1.01	56.47	16.7	71	A	0	
3	0.11	0.15	0.34	0.023	0.007	14.85	8.93	0.01	0.005	0.20	0.002	0.001	0.001	0.01	0.01	1.71	56.08	10.1	70	A	0	
4	0.11	0.18	0.35	0.018	0.002	14.32	11.71	0.01	0.005	0.01	0.005	0.001	0.001	0.01	0.01	1.85	58.66	16.1	75	A	0	
5	0.10	0.21	0.03	0.010	0.004	17.94	4.06	0.01	0.021	0.16	0.010	0.001	0.001	0.01	0.01	2.39	61.51	10.3	71	A	0	
6	0.12	0.23	0.46	0.001	0.007	17.12	8.98	0.03	0.16	0.01	0.001	0.10	0.001	0.01	0.01	1.36	59.61	16.5	80	A	0	
7	0.11	0.22	0.38	0.002	0.001	19.78	3.15	0.12	0.005	0.01	0.001	0.001	0.02	0.01	0.01	2.09	62.72	10.4	74	A	0	
8	0.01	0.16	0.48	0.036	0.002	21.06	6.71	0.02	0.02	0.06	0.001	0.001	0.03	0.01	0.01	3.05	74.54	16.7	78	A	0	
9	0.11	0.22	0.38	0.021	0.003	22.01	3.11	0.001	0.03	0.52	0.005	0.001	0.001	0.01	0.01	2.23	64.64	19.3	79	A	0	
10	0.01	0.17	0.41	0.034	0.006	22.46	8.81	0.01	0.01	0.24	0.001	0.13	0.001	0.01	0.01	3.65	83.33	18.1	78	A	0	
11	0.11	1.00	0.21	0.021	0.005	24.97	1.09	0.02	0.005	0.01	0.005	0.03	0.001	0.01	0.01	2.16	74.53	18.3	85	A	0	
12	0.12	0.23	0.41	0.010	0.004	22.2	3.0	0.01	0.005	0.18	0.005	0.04	0.001	0.06	0.06	2.22	69.12	19.4	80	A	0	
13	0.02	0.74	0.71	0.012	0.003	25.2	8.6	0.01	0.005	0.00	0.005	0.05	0.002	0.03	0.12	3.78	90.51	18.1	80	A	0	
14	0.01	0.02	0.51	0.023	0.007	20.5	5.5	0.01	0.005	0.20	0.002	0.001	0.001	0.01	0.01	2.72	77.35	18.8	80	A	0	
15	0.01	0.74	0.73	0.018	0.002	20.3	5.7	0.01	0.005	0.16	0.005	0.001	0.001	0.01	0.01	2.75	70.06	18.8	78	A	0	
16	0.01	0.60	0.98	0.019	0.004	20.4	5.8	0.01	0.005	0.01	0.005	0.001	0.001	0.01	0.01	2.78	70.58	18.8	78	A	0	
17	0.02	0.41	0.09	0.001	0.007	20.8	5.2	0.03	0.031	0.01	0.001	0.10	0.001	0.01	0.01	2.65	70.38	18.8	78	A	0	
18	0.03	0.38	0.02	0.002	0.001	20.9	5.3	0.12	0.005	0.08	0.001	1.42	0.001	0.01	0.01	2.60	70.82	18.2	81	A	0	
19	0.02	1.52	1.01	0.036	0.002	20.1	8.4	0.02	0.021	0.00	0.001	0.001	0.02	0.01	0.01	2.66	68.81	18.8	77	A	0	
20	0.04	0.68	2.03	0.021	0.003	20.7	8.9	0.001	0.008	0.14	0.001	0.001	0.65	0.01	0.01	2.43	71.65	18.5	80	A	0	
21	0.05	0.34	0.67	0.034	0.006	20.4	5.1	0.01	0.005	1.70	0.005	0.001	0.31	1.87	0.01	2.61	68.05	18.8	78	A	0	
22	0.01	0.22	4.82	0.037	0.005	20.3	5.5	0.08	0.027	0.02	0.001	0.40	0.001	0.01	1.97	2.70	69.60	19.2	81	A	0	

[0020]

Table 1 shows that the traditional alloys A1 and A2 exhibit excellent characteristics for a high expansion component of bimetallic applications, because they are single phase austenite at room temperature and have a high thermal expansivity as well as a high electrical resistivity. However, they suffer from a poor workability at high temperatures.

The alloys proposed by this invention, which contain a proper amount of B, Ti, or Zr, demonstrate a remarkably higher workability at high temperatures. In these alloys, T is equal to 3.9 or less, E is equal to 55.0 or more, α is equal to $18 \times 10^{-6}/^{\circ}\text{C}$ or more, and ρ is equal to $70 \mu\Omega\text{cm}$ or more. In other words, the alloys of this invention exhibit thermal expansivities and electrical resistivities similar to those of the traditional alloys. On the other hand, the alloys for comparison C1 to C10, which contain Ti and Zr not falling within the range proposed by this invention, generate considerable edge cracking in hot-working processes. Furthermore, alloys for comparison C11 to C17 are not suitable for a high expansion element of bimetals, because their values for both α and ρ are too low, due to their phase structure.

[0021]

[Advantageous effect]

As described above, the alloy of this invention having a thermal expansivity and an electrical resistivity similar to those of the traditional Fe-Ni-Cr alloys such as the Fe-22 Ni-3Cr alloy or the Fe-25 Ni-8.5 Cr alloy, and a remarkably improved workability at high temperatures, offers a good production yield and a higher productivity. This invention consequently can be, therefore, credited with an extremely high industrial value.

[0022]

[Description of Drawings]

FIGURE 1 shows reductions in area measured by a high temperature tensile test ($1,000^{\circ}\text{C}$) at a strain rate of 1/sec submitted to two series of steel alloys with single phase austenite structure, the first with boron and the second without boron.

FIGURE 2 shows influences of boron contents on reduction in area measured by a high temperature tensile test ($1,000^{\circ}\text{C}$) at a strain rate of 1/sec., electrical resistivity at room temperature, and thermal expansivity in the temperature range from 30 to 100°C .

FIGURE 3 shows influences of titanium contents on reduction in area measured by a high temperature tensile test ($1,000^{\circ}\text{C}$) at a strain rate of 1/sec., electrical resistivity at room temperature, and thermal expansivity in the temperature range from 30 to 100°C .

FIGURE 4 shows influences of zirconium contents on reduction in area measured by a high temperature tensile test ($1,000^{\circ}\text{C}$) at a strain rate of 1/sec., electrical resistivity at room temperature, and thermal expansivity in the temperature range from 30 to 100°C .

[0023]

FIGURE 5 shows correlation between values of $T = 0.067 \times (\% \text{ Ni}) + 0.244 \times (\% \text{ Cr})$ and coefficients of thermal observed in alloys presenting a single-phase austenite structure at room temperature and that observed in an alloy presenting an austenite/martensite phase at room temperature.

FIGURE 6 shows correlation between values of $E = 2.80 \times (\% \text{ Ni}) + 2.32 \times (\% \text{ Cr})$ and electrical resistivities observed in alloys presenting a single phase austenite structure at room

temperature and that observed in an alloy presenting an austenite/martensite phase at room temperature.

[TABLE 2]

Table 1 (continued)

No.	Chemical composition (mass %)													T	E	C. T. E. ($\times 10^{-6}/^{\circ}\text{C}$ 30-160°C)	Electrical resistivity at room temperature ($\mu\Omega\text{cm}$)	Structure at room temperature	Edge cracking length	Remark
	C	Si	Mn	P	S	Al	Cr	N	Ag	Co	B	Ti	Zr	Cu	K ₀					
B-23	0.03	0.56	0.20	0.002	0.003	0.005	7.3	0.08	0.005	0.56	0.002	0.03	0.01	0.07	0.05	18.2	74	A	0	Alloys proposed by this invention
24	0.17	0.71	0.78	0.006	0.001	<0.005	8.8	0.01	<0.005	0.24	0.007	0.55	0.02	0.01	0.05	18.5	71	A	0	
25	0.31	0.39	0.41	0.033	0.007	0.21	0.8	0.18	0.005	0.08	0.009	0.02	0.04	0.08	0.01	18.1	83	A	0	
26	0.01	0.38	0.38	0.021	0.007	2.03	8.1	0.01	0.005	0.12	0.006	0.01	0.78	0.57	0.03	18.6	94	A	0	
27	0.01	2.14	0.56	0.003	0.004	0.87	2.1	0.05	0.005	0.18	0.004	0.78	0.01	0.12	0.56	18.4	83	A	0	
C-1	0.01	0.18	0.58	0.021	0.003	<0.005	29.3	0.01	<0.005	<0.01	<0.001	<0.001	<0.001	<0.01	<0.01	18.8	77	A	20	
2	0.12	0.22	0.39	0.018	0.002	<0.005	17.71	0.01	<0.005	<0.01	<0.001	<0.001	<0.001	<0.01	<0.01	17.3	67	A	15	
3	0.12	0.24	0.39	0.016	0.004	<0.005	14.80	0.01	<0.005	0.12	<0.001	<0.001	<0.001	<0.01	<0.01	17.5	68	A	15	
4	0.10	0.18	0.37	0.023	0.005	<0.005	13.27	0.01	<0.005	0.03	<0.001	<0.001	<0.001	<0.01	<0.01	17.7	70	A	15	
5	0.11	0.51	0.58	0.021	0.007	<0.005	3.89	<0.01	<0.005	0.01	<0.001	<0.001	<0.001	<0.01	<0.01	17.7	86	A	15	Alloys for comparison
6	0.02	0.23	0.72	0.018	0.005	<0.005	5.4	0.01	<0.005	<0.01	0.032	<0.001	<0.001	<0.01	<0.01	18.8	77	A	16	
7	0.01	0.21	0.51	0.023	0.004	<0.005	20.6	0.02	<0.005	0.21	<0.001	2.29	<0.001	<0.01	<0.01	17.7	84	A	15	
8	0.02	0.19	0.79	0.033	0.005	<0.005	5.6	0.03	<0.005	0.18	<0.001	<0.001	1.58	<0.01	<0.01	18.2	82	A	17	
9	0.01	0.18	0.62	0.018	0.005	<0.005	20.5	0.01	<0.005	0.12	0.005	<0.001	0.71	0.02	<0.01	17.8	71	A	0	
10	0.03	0.22	0.54	0.019	0.002	<0.005	20.4	0.03	<0.005	0.21	0.004	0.18	<0.001	<0.01	4.98	17.9	82	A	0	
11	0.12	0.22	0.38	0.024	0.003	<0.005	9.96	<0.01	<0.005	0.01	0.007	<0.001	<0.001	<0.01	<0.01	11.6	81	A+H	0	
12	0.12	0.24	0.37	0.017	0.001	<0.005	14.01	0.01	<0.005	0.51	<0.001	0.72	<0.001	<0.01	<0.01	15.3	73	A+H	0	
13	0.12	0.18	0.94	0.015	0.004	<0.005	7.04	<0.01	<0.005	0.28	<0.001	<0.001	0.59	<0.01	<0.01	16.9	73	A+H	0	
14	0.12	0.15	0.34	0.018	0.004	<0.005	14.79	<0.01	<0.005	0.03	0.003	0.38	<0.001	<0.01	<0.01	11.4	56	A+B	0	
15	0.13	0.16	0.35	0.021	0.002	<0.005	17.36	<0.01	<0.005	0.15	0.006	<0.001	0.28	<0.01	<0.01	15.3	64	A+H	0	
16	0.11	0.20	0.36	0.019	0.005	<0.005	18.92	<0.01	<0.005	0.32	<0.001	0.48	0.12	<0.01	<0.01	16.4	68	A+H	0	
17	0.12	0.16	0.42	0.023	0.003	<0.005	21.68	<0.01	<0.005	0.05	0.004	0.52	0.06	<0.01	<0.01	17.9	69	A+B	0	

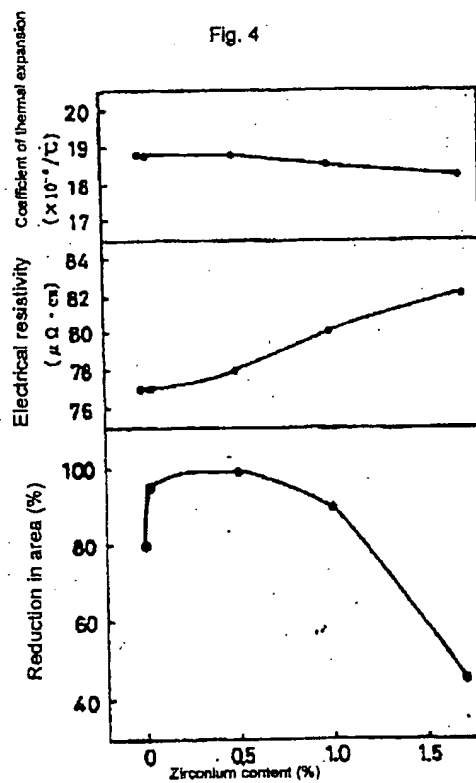
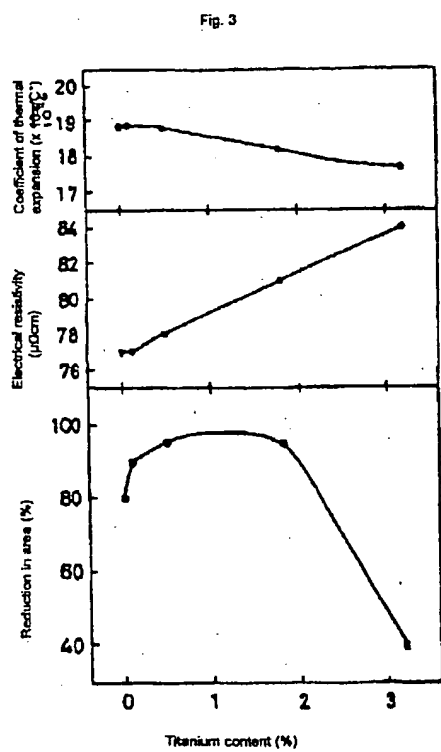
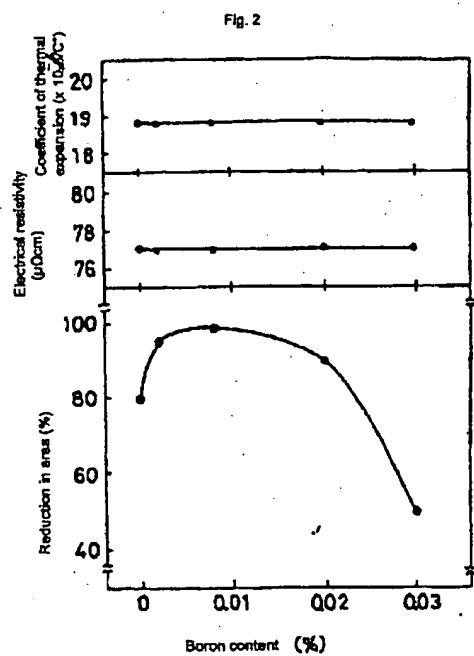
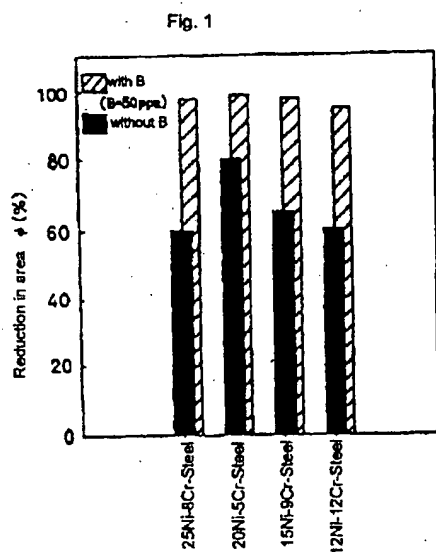


Fig.5

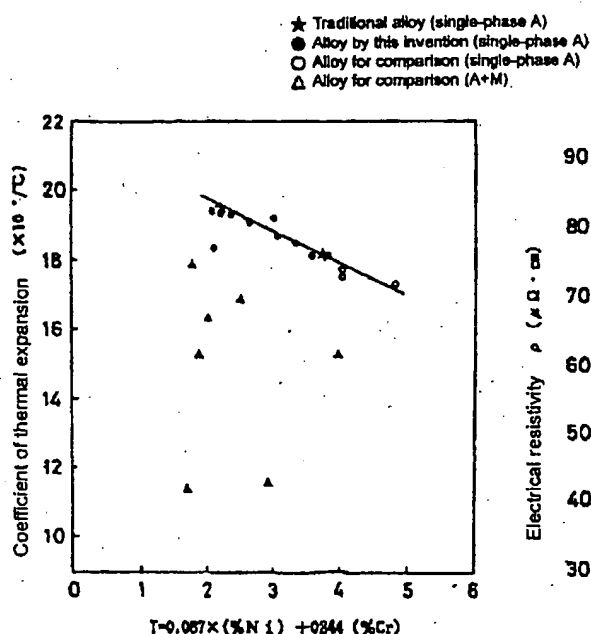
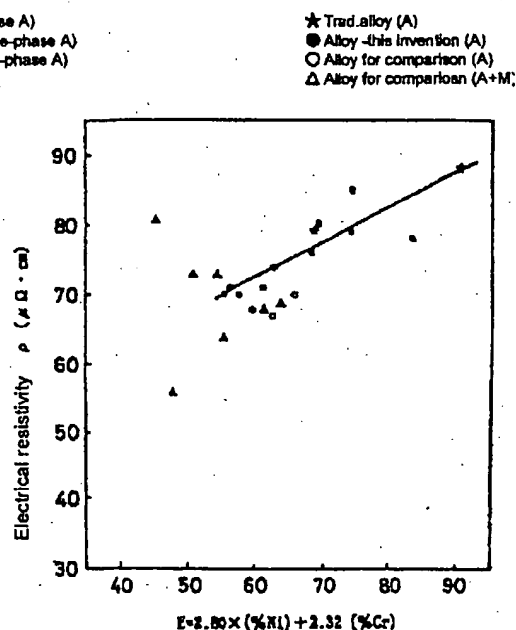


Fig. 6



[Appeal against the decision]

[Date of appeal] 13.09.1993

[Amended Document] Description

[Amended Item] Description of Drawings

[Nature of Amendment] Modifications

[Details of Amendment]

[Description of Drawings]

[FIGURE 1]

Reduction in area measured by a high temperature tensile test (1,000°C) at a strain rate of 1/sec submitted to two series of steel alloys with single-phase austenite structure, the first with boron and the second without boron

[FIGURE 2]

Influence of boron contents on reduction in area measured by a high temperature tensile test (1,000°C) at a strain rate of 1/sec., electrical resistivity at room temperature, and thermal expansivity in the temperature range from 30 to 100°C

[FIGURE 3]

Influence of titanium contents on reduction in area measured by a high temperature tensile test (1,000°C) at a strain rate of 1/sec., electrical resistivity at room temperature, and thermal expansivity in the temperature range from 30 to 100°C

[FIGURE 4]

Influence of zirconium on reduction in area measured by a high temperature tensile test (1,000°C) at a strain rate of 1/sec., electrical resistivity at room temperature, and thermal expansivity in the temperature range from 30 to 100°C

[FIGURE 5]

Correlation between values of $T = 0.067 \times (\% \text{ Ni}) + 0.244 \times (\% \text{ Cr})$ and coefficients of thermal expansion of alloys exhibiting a single phase austenite structure at room temperature and that of an alloy exhibiting an austenite/martensite phase at room temperature

[FIGURE 6]

Correlation between values of $E = 2.80 \times (\% \text{ Ni}) + 2.32 \times (\% \text{ Cr})$ and electrical resistivities of alloys exhibiting a single-phase austenite structure at room temperature and that of an alloy exhibiting an austenite/martensite phase at room temperature

Continued from the front page

(72) Inventor

TAKEMOTO Toshihiko
Section Stainless and High Alloy Steel
Nisshin Steel Co. Ltd. Research Institute
4976, Nomura-minami-machi, Shin Nan'yo City
Prefecture of Yamaguchi

(72) Inventor

BABAZONO Katsunori
Section Stainless and High Alloy Steel
Nisshin Steel Co. Ltd. Research Institute
4976, Nomura-minami-machi, Shin Nan'yo City
Prefecture of Yamaguchi